

Gamma Spectrometric techniques for Ultra Low Activity Measurements

Underground Facilities

Anti Cosmic and Anti Compton Radiation Shield Systems

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Why Low Activity Measurements are needed ???

- 40-50 years after the introduction of anthropogenic radionuclides into the environment their concentrations have decreased considerably
- Highly accurate and precise data are required for environmental and climate change studies
- Sample size for radiometrics analyses should be comparable to mass spectrometry requirements

Developments in radiometrics techniques :

- *The operation of high efficiency HPGe detectors often placed underground*

Low activity → High efficiency detector

High efficiency detector → Higher sensitivity to background and cosmic rays

Sensitivity to the background → Ultra low Background Lead Shield

Sensitivity to the cosmic rays → Deep Underground Lab

- *Anti-cosmic and anti-Compton shielding of detectors*

Not deep enough U-Lab → Anti Cosmic shield

Background coming from sample → Anti-Compton system

- *Coincidence gamma-ray spectrometry
(γ - γ , β - γ , β - γ - γ , etc.)*

Background still too high → γ - γ coincidences

Background still too high → β - γ , β - γ - γ , coincidences etc ...

Nucleonica MONACO 12-15Th October 2010

Underground Laboratory



MEL Underground Laboratory

Marine Environment Laboratory

Place d'Armes
Market

11m = 35 mwe

500m

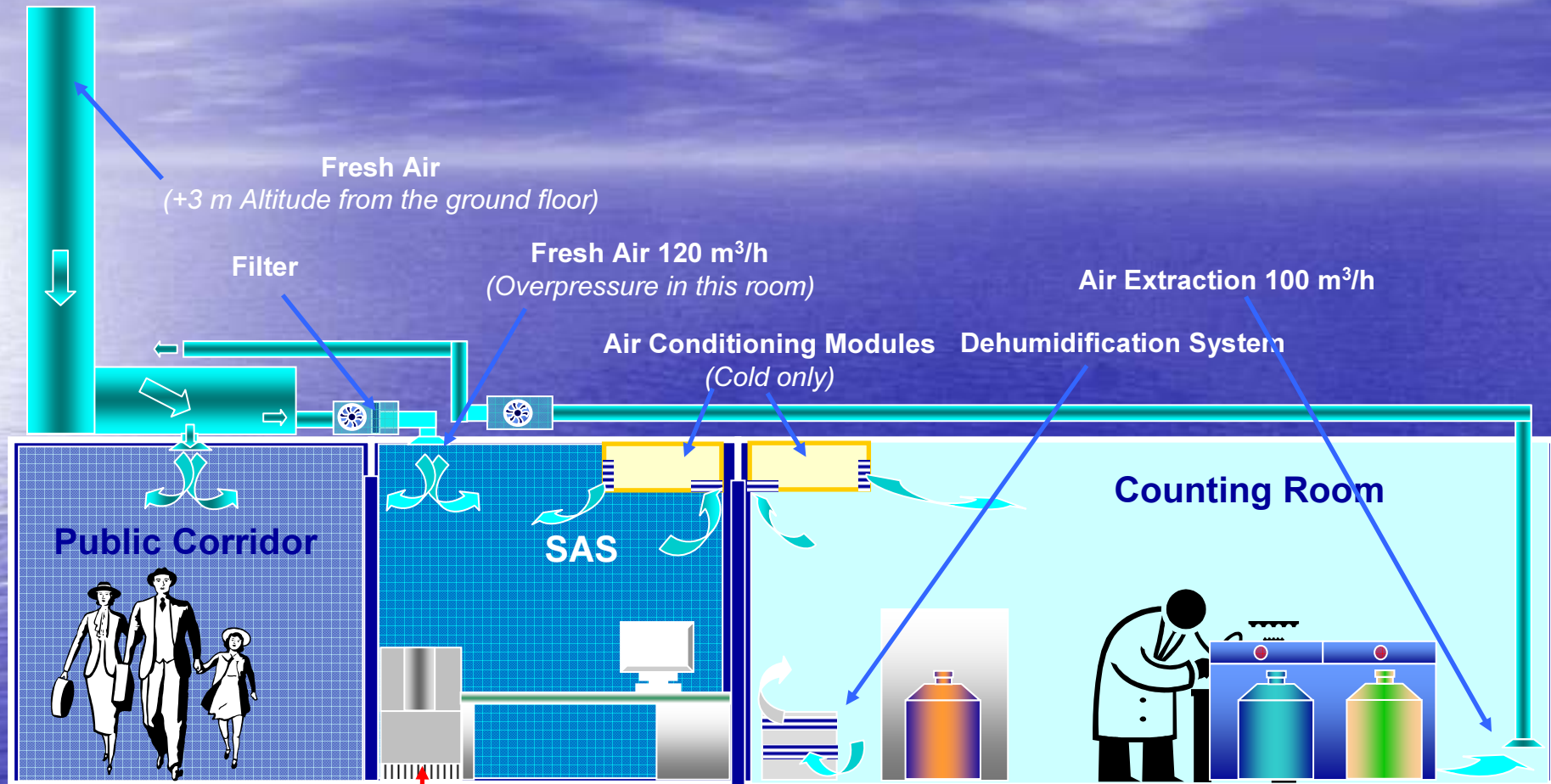
Cosmic radiations attenuation
depending on the rock thickness

Depth	Attenuation
5 m	100
10 m	100 000
50 m	10 000 000
100 m	100 000 000
1000 m	1 000 000 000



UNDERGROUND LABORATORY

Fresh Air, Air Conditioning, Electricity



UPS 5 kVA (Supplied by an Electric Generator in case of electricity breakdown)

MEL Underground Laboratory

Anti-Compton Spectrometer **4 Anti-Cosmic Spectrometers** **BE-Ge Spectrometer**



Radon Spectrometer

70 % Well Type Spectrometer

ULB Liquid scintillation Spectrometer

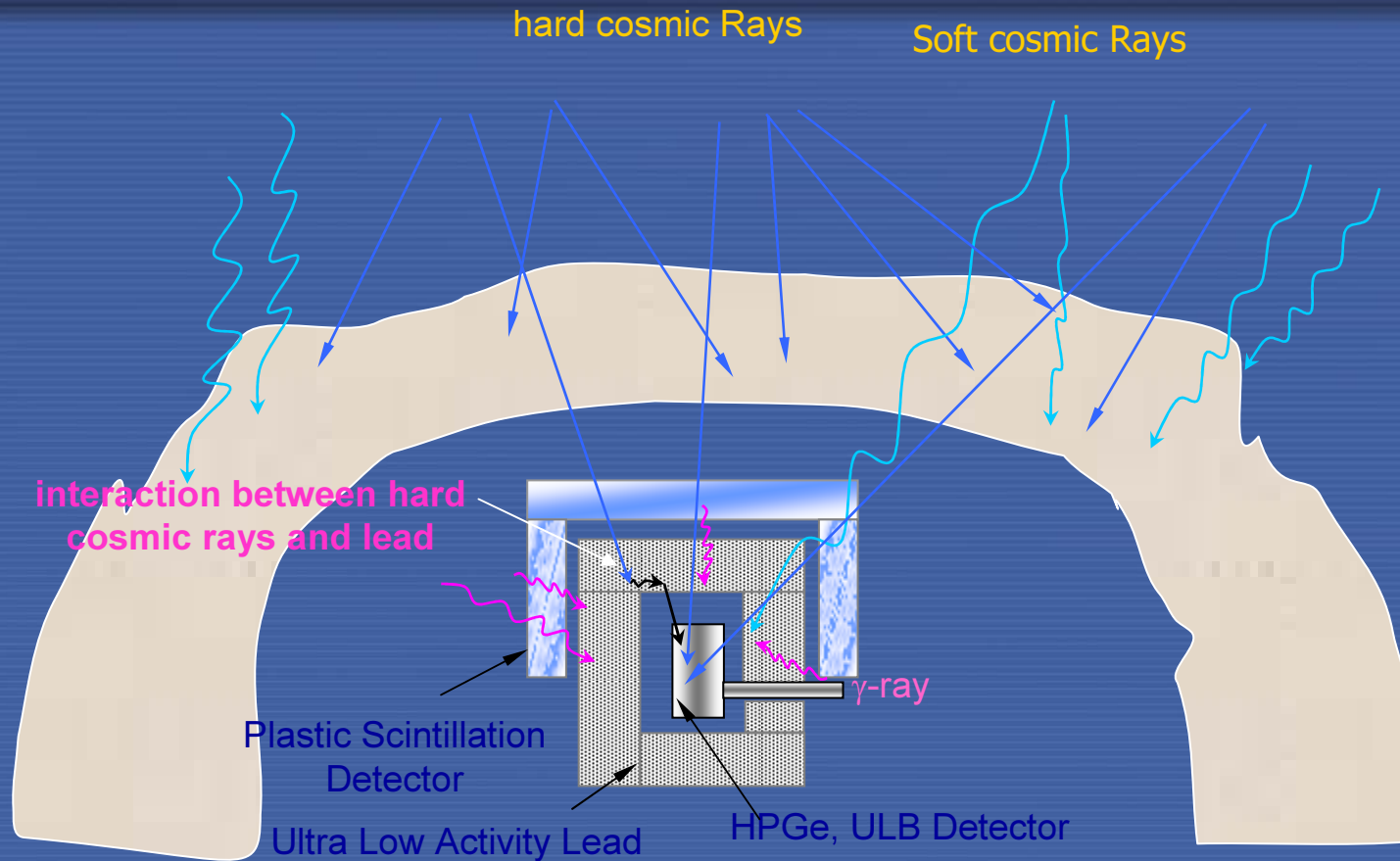


Anti-cosmic Spectrometers



Anti-cosmic spectrometers

Principle



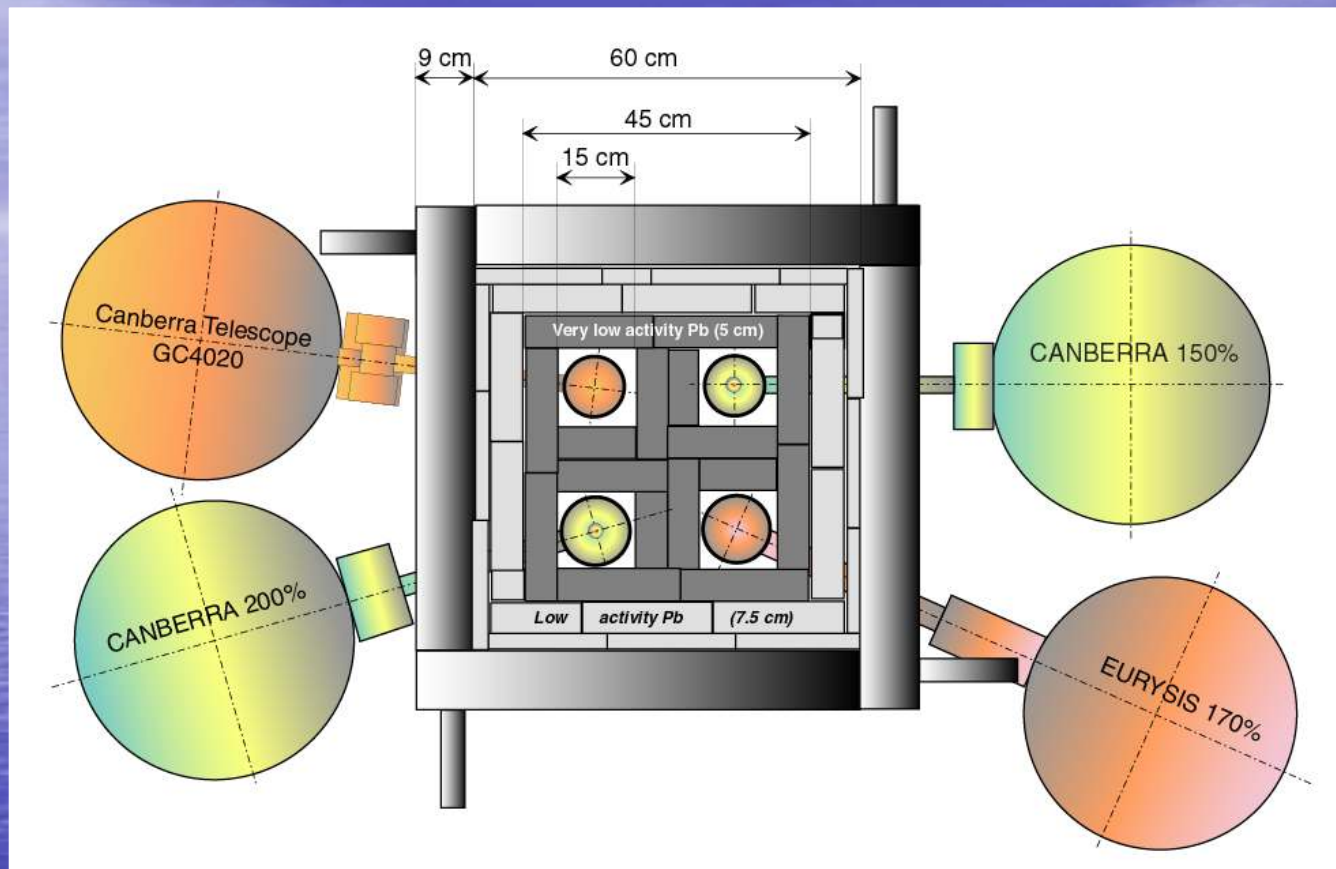
The system operates in anti-coincidence mode



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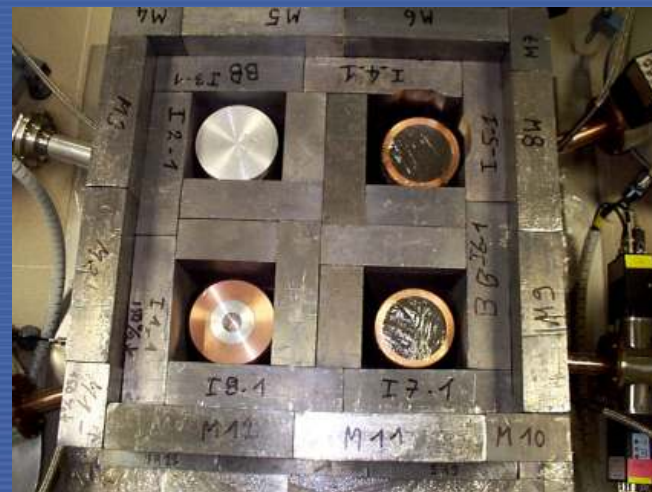
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View of the lead shield with anti-cosmic plastic scintillation shielding

Anti-Cosmic Spectrometers



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Anti-cosmic Spectrometers

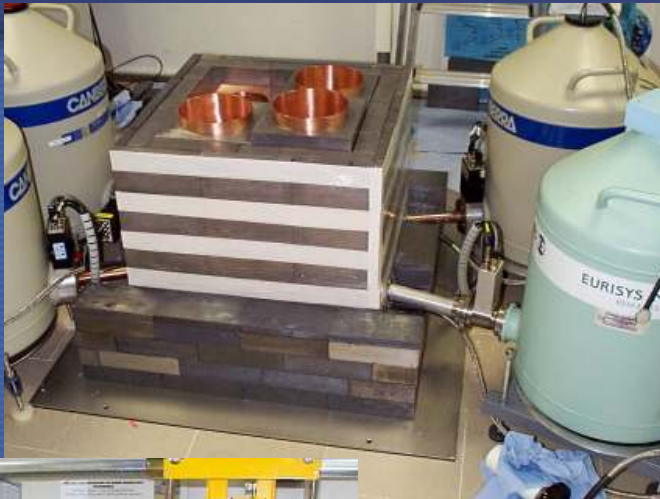


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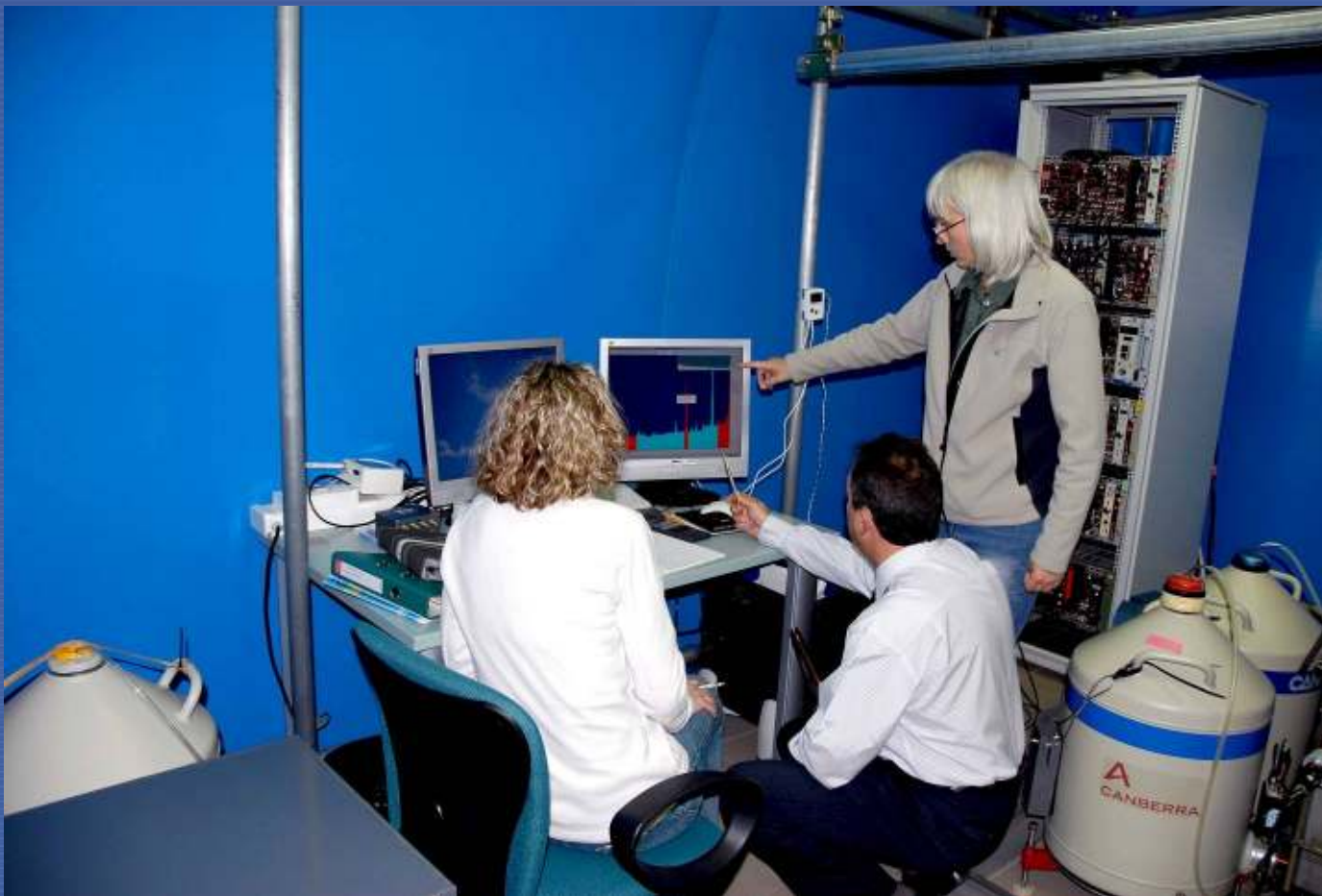
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Anti-Cosmic Spectrometers



Anti-cosmic Spectrometers

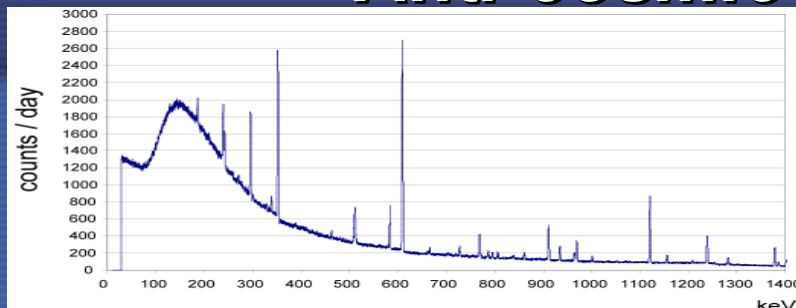


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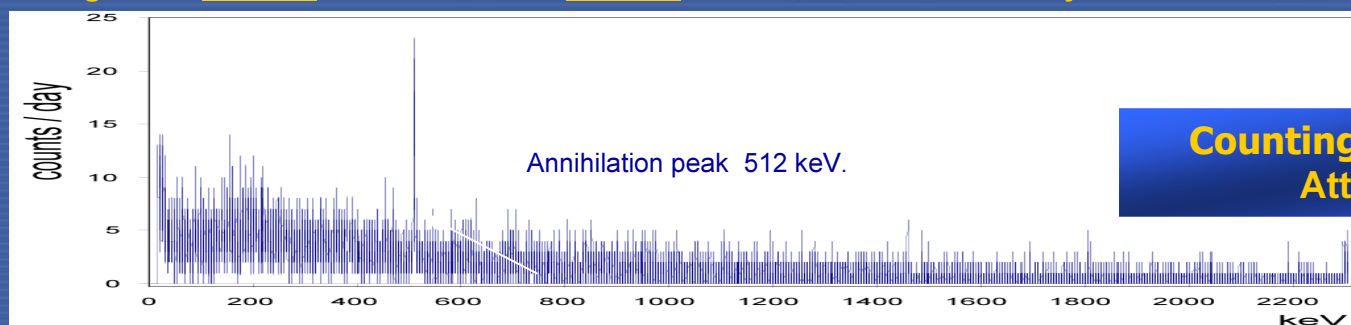


Anti-cosmic Spectrometers



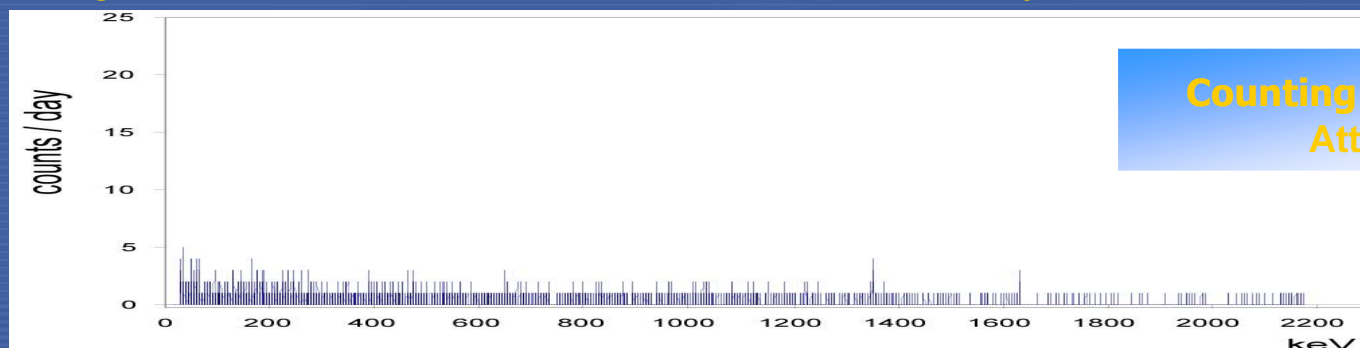
Counting rate = $5,2 \cdot 10^6$ c/d
Attenuation: 5

Background without lead shield and without electronic anti-cosmic system.



Counting rate = $1,728 \cdot 10^4$ c/d
Attenuation : 307

Background with lead shield and without electronic anti-cosmic system.



Counting rate = $1,728 \cdot 10^3$ c/d
Attenuation : 10

Background with lead shield and with electronic anti-cosmic system.



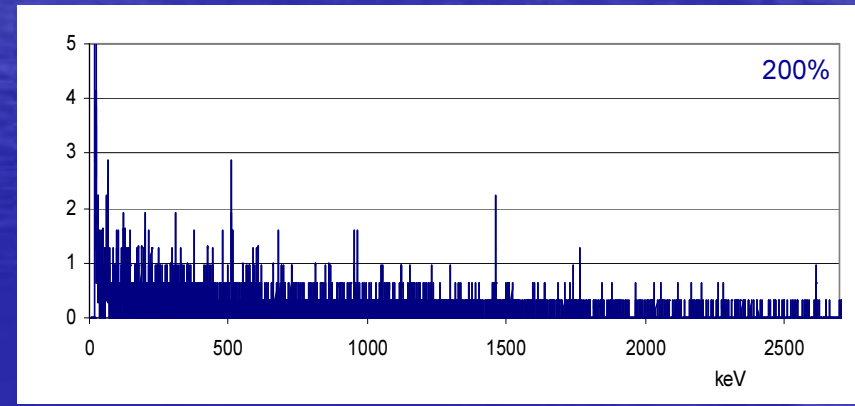
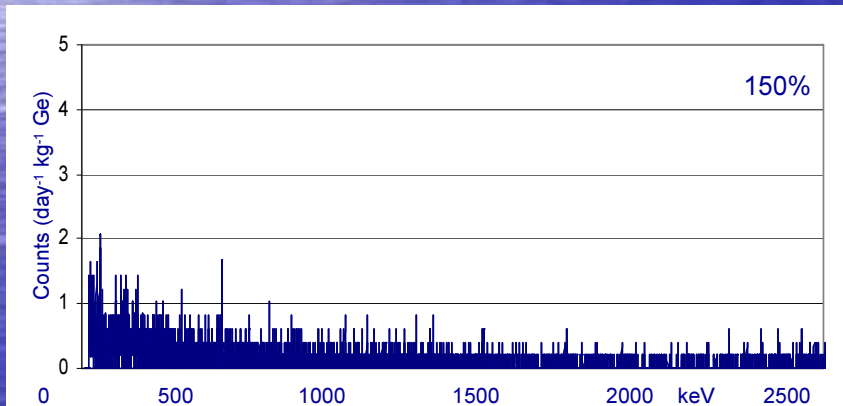
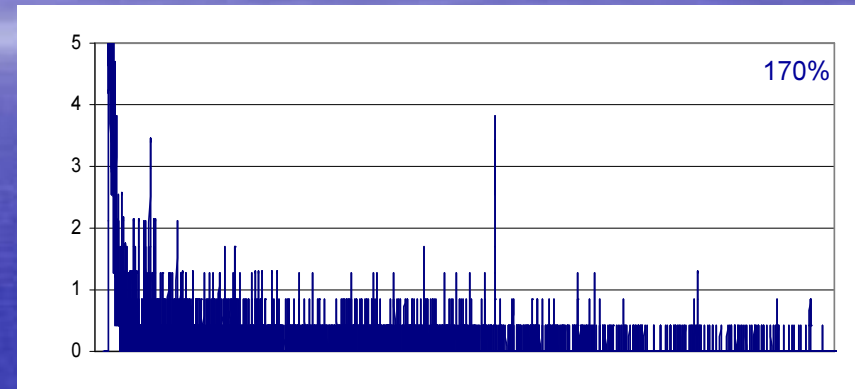
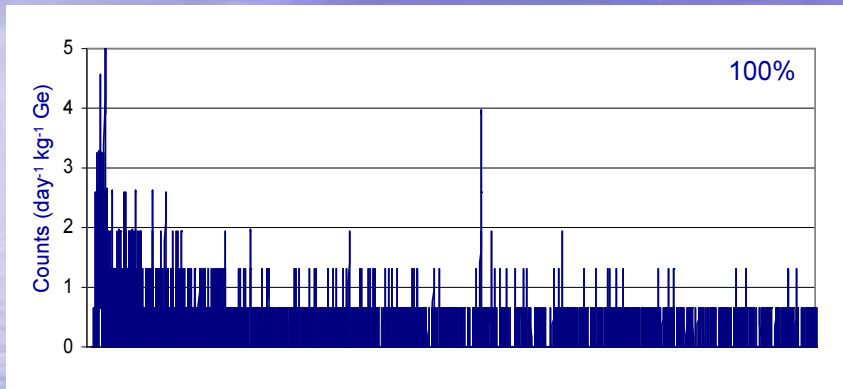
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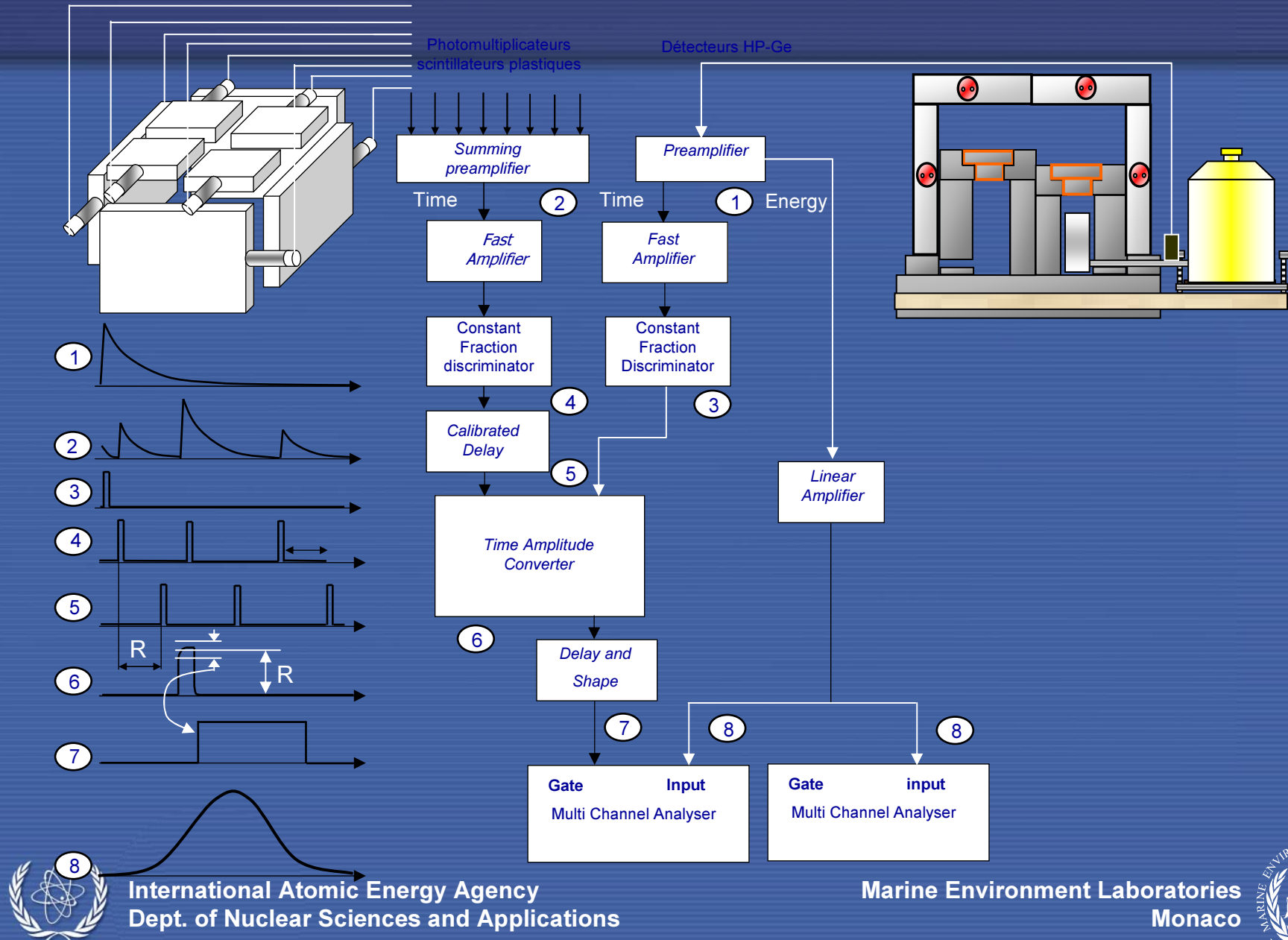


Anti-cosmic Spectrometers

BACKGROUND GE-SPECTRA WITH ANTICOSMIC SHIELDING



Anti-cosmic Spectrometers



Anti-cosmic Spectrometers

Comparison with other U-Lab

Low-background gamma spectroscopy for environmental spectroscopy T.M. Semkow and all. Applied Radiation and Isotopes 57, 213-2232002

Localization Meters Water Equivalent (mwe).	Active Shield	Volume of Ge (Cm ³)	Energy Range (keV)	Background (c/s/100cm ³)	References
Ground Level	Plastic Scintillator 4 faces	131	40-3000	$2,1 \times 10^{-1}$	Shizuma (1992)
Ground Level	Proportional Counter at the top	180	50-1500	$1,4 \times 10^{-1}$	Vojtyla (1994)
Ground Level	Plastic Scintillator	196	30-2700	$8,7 \times 10^{-2}$	Laurec (1996)
<33 mwe*	Plastic Scintillator at the top	485	50-2700	$6,8 \times 10^{-2}$	Semkov (2002)
Ground Level	NaI Scintillator	125	25-1600	$5,4 \times 10^{-2}$	El-Daoushi (1995)
30 mwe	None	487	30-2700	$4,2 \times 10^{-2}$	MEL Ulab
Ground Level	Plastic Scintillator	125	100-2000	$4,1 \times 10^{-2}$	Miley (1992)
15 mwe	Proportional Counter	170	50-2680	$2,7 \times 10^{-2}$	Heusser (1991)
5 mwe	NaI Scintillator	106	20-4000	$9,4 \times 10^{-3}$	Beda (2000)
500 mwe	None	40	20-2700	$9,4 \times 10^{-3}$	Mouchel (1996)
4400 mwe	None	207	20-2000	$8,2 \times 10^{-3}$	Bourlat (1994)
30 mwe	Plastic Scintillator 5 faces	487	30-2700	$5,8 \times 10^{-3}$	MEL Ulab
500 mwe	None	234	40-2700	$2,0 \times 10^{-3}$	Hult (2000)
800 mwe	None	560	100-2200	$9,9 \times 10^{-4}$	Jagam (1988)
3300 mwe	None	411	50-2750	$6,1 \times 10^{-4}$	Neder (2000)
4000 mwe	None	200	100-2000	$1,3 \times 10^{-4}$	Miley (1992)



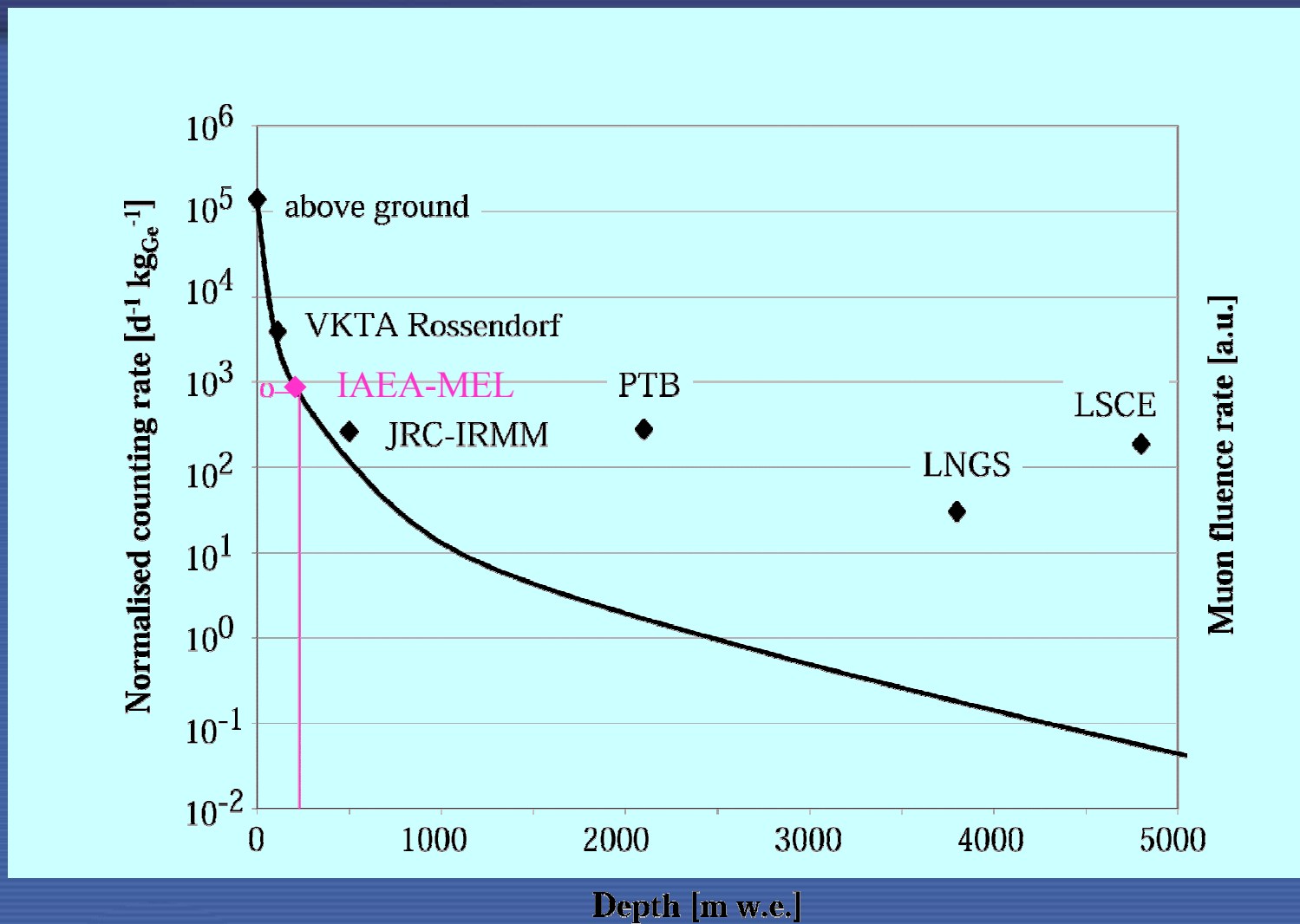
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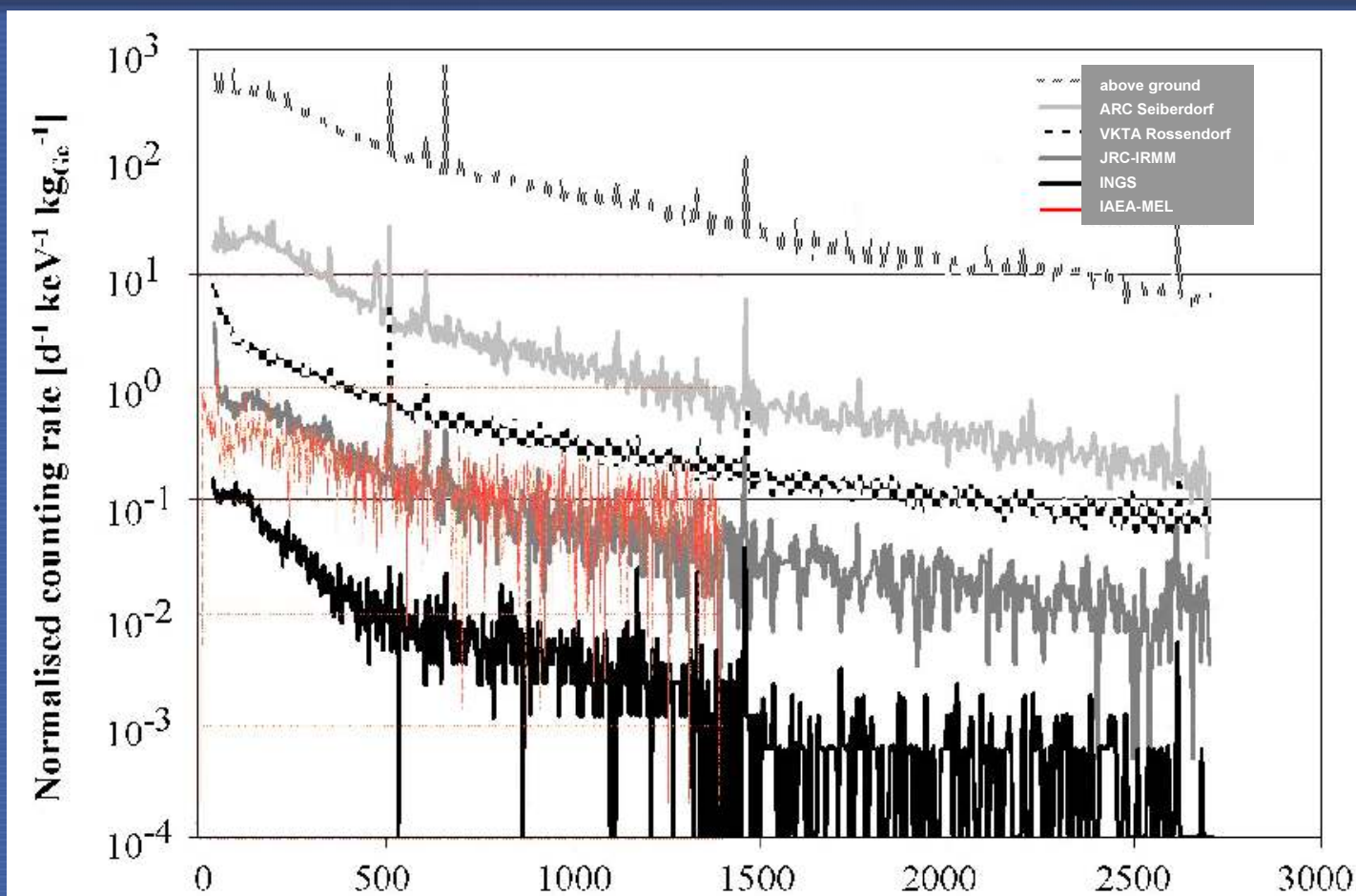
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Comparison with other U-Lab

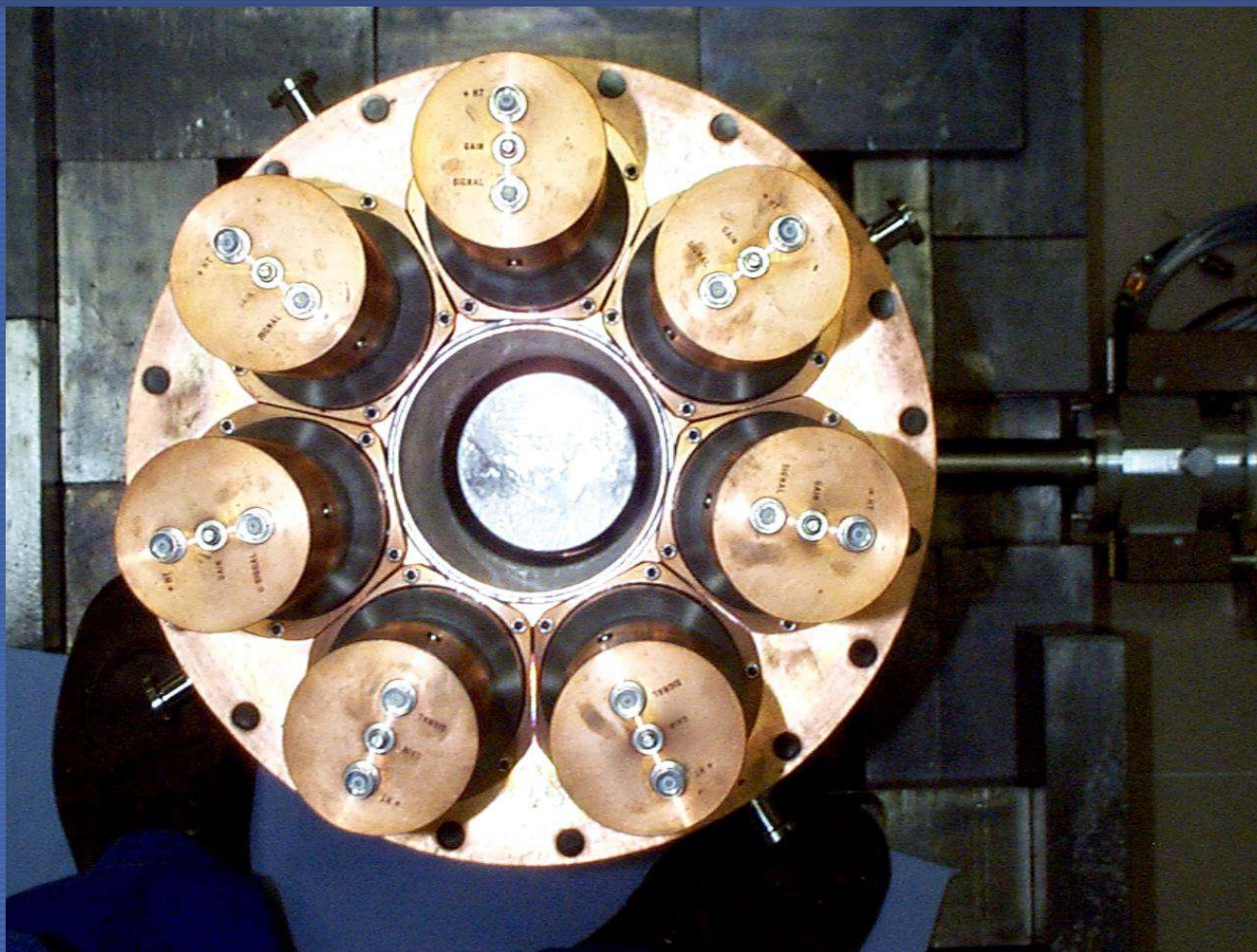


Anti-cosmic Spectrometers

Comparison with other U-Lab



The Anti-Compton Spectrometer

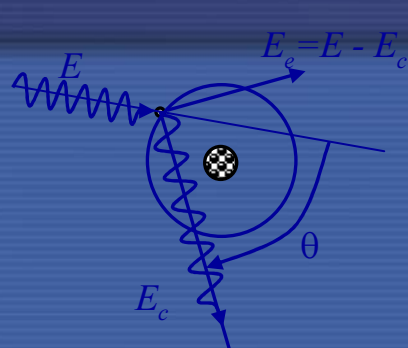


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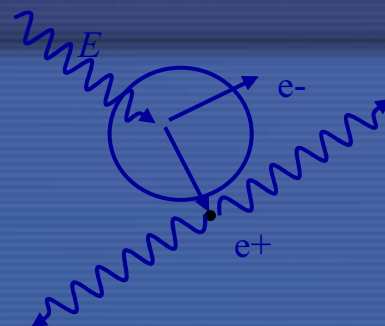
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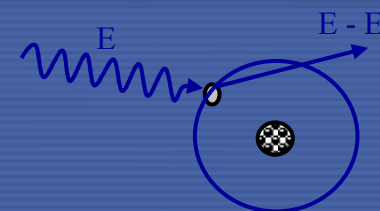
Anti-Compton Spectrometer and Marine Samples



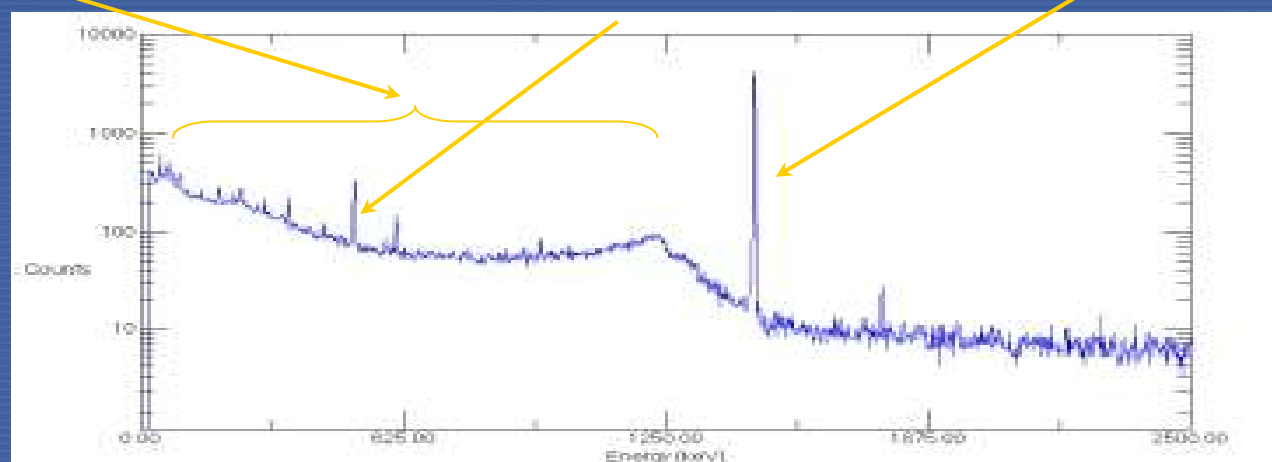
Compton Effect
(continuous distribution)



Pair Production
(512 keV)



Photoelectric Effect
(Pic ^{40}K (1460 keV))



Marine Salt Gamma Spectrum

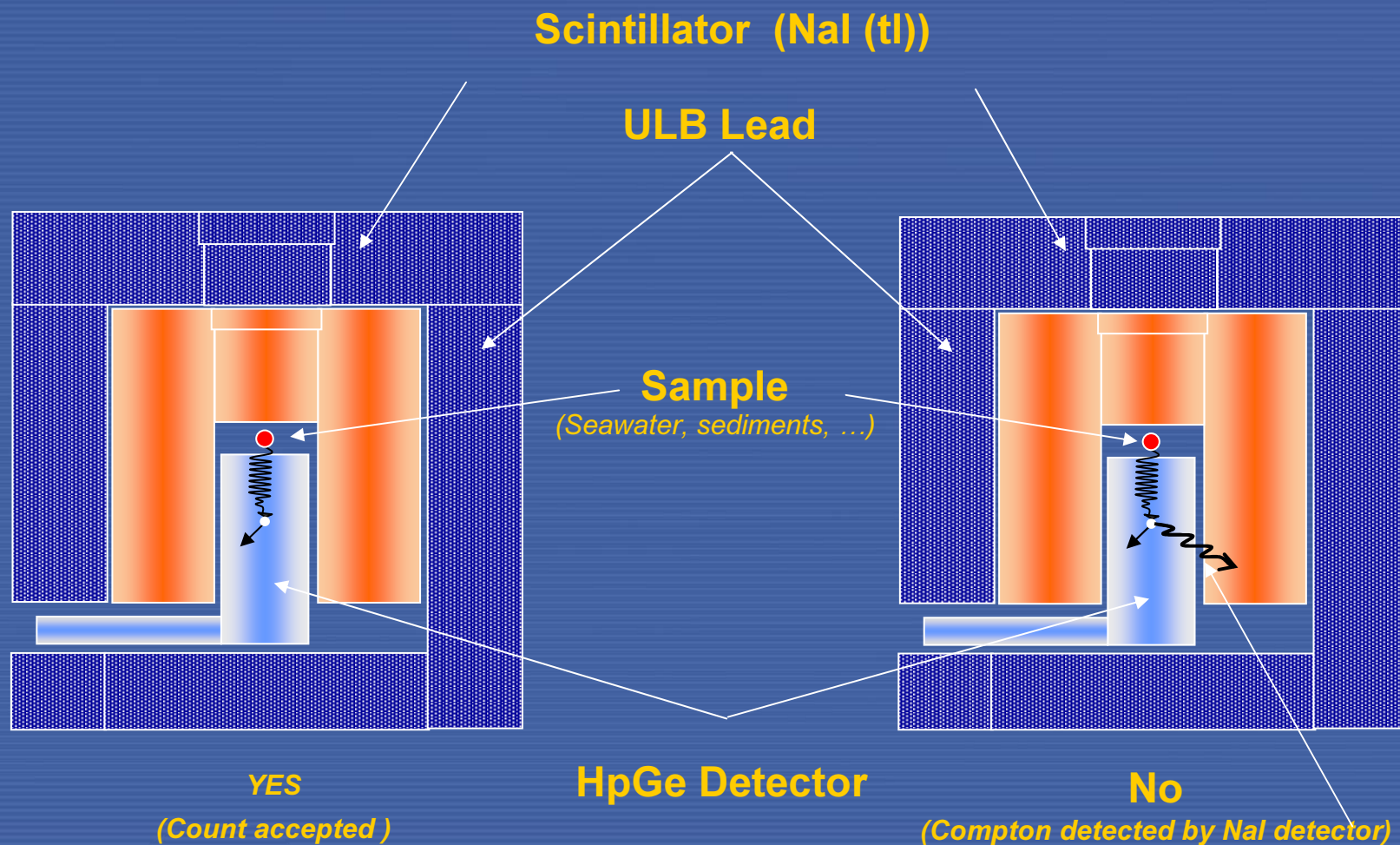


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The Anti-Compton Spectrometer



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The Anti-Compton Spectrometer

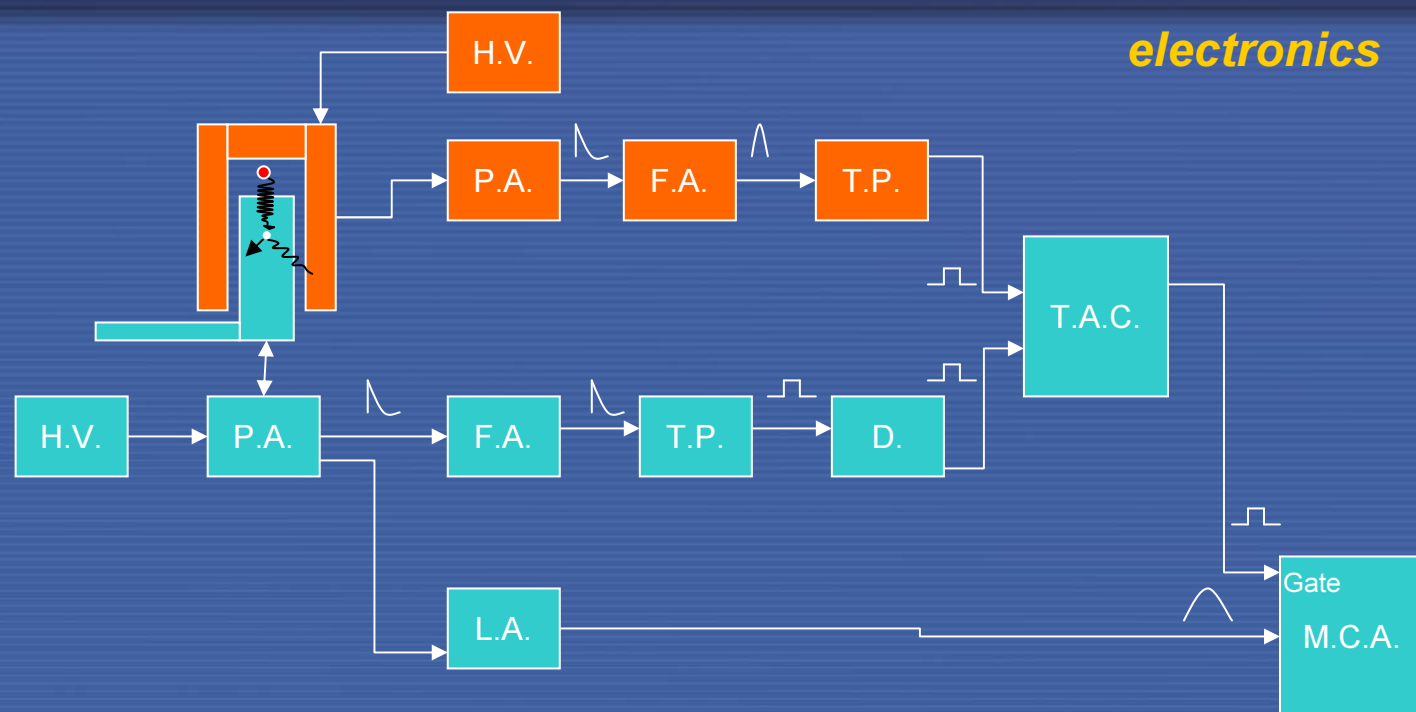


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The Anti-Compton Spectrometer



H.T. : High Voltage

A.R. : Fast Amplifier

S.C.A. : Single Channel Analyzer

P.A. : Preamplifier

L.A. : Linear Amplifier

M.C.A. : Multi Channel Analyzer

T.A.C. : Time Amplitude Converter

D. : Delay

T.P. : Time Pickoff



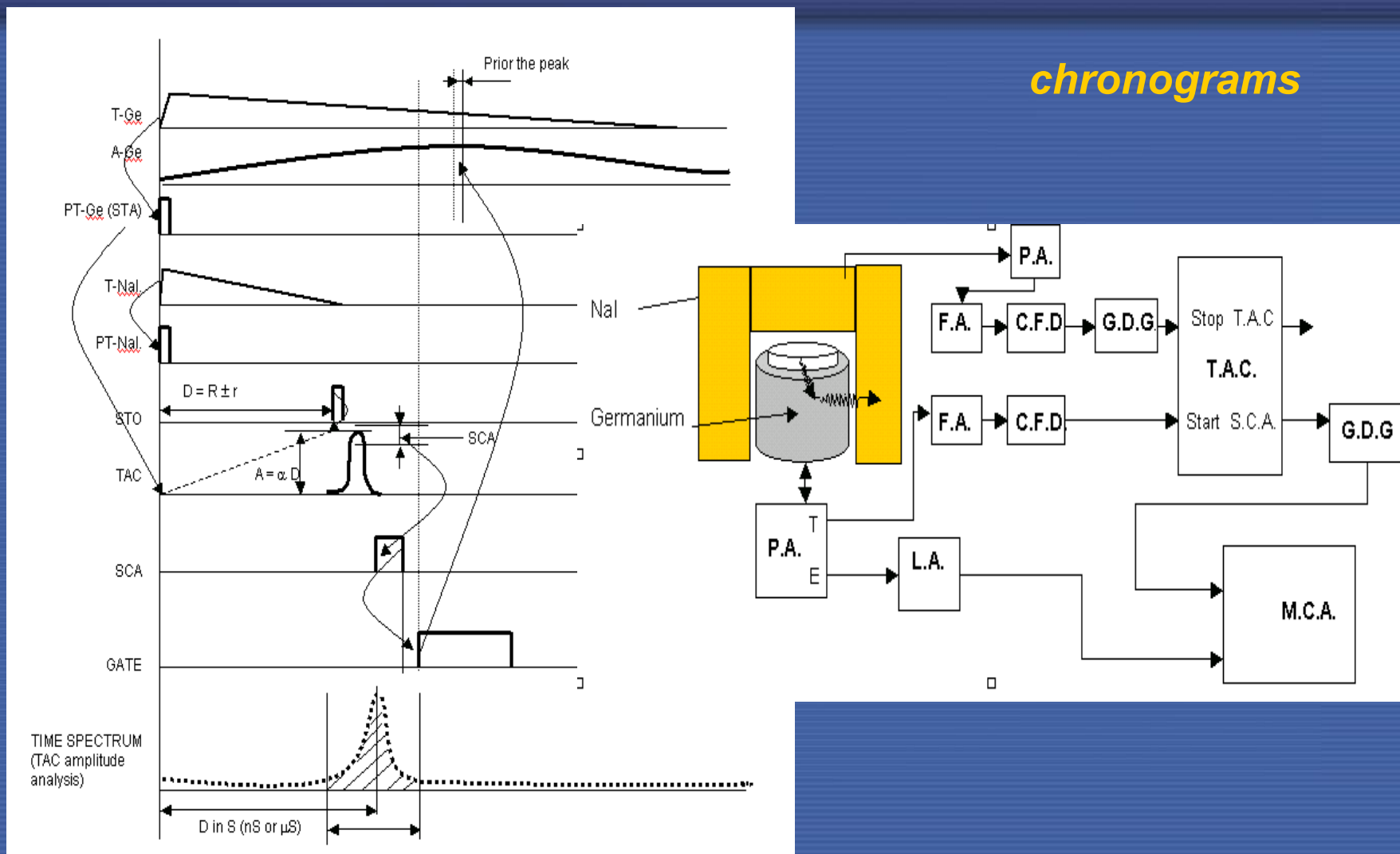
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The Anti-Compton Spectrometer

chronograms



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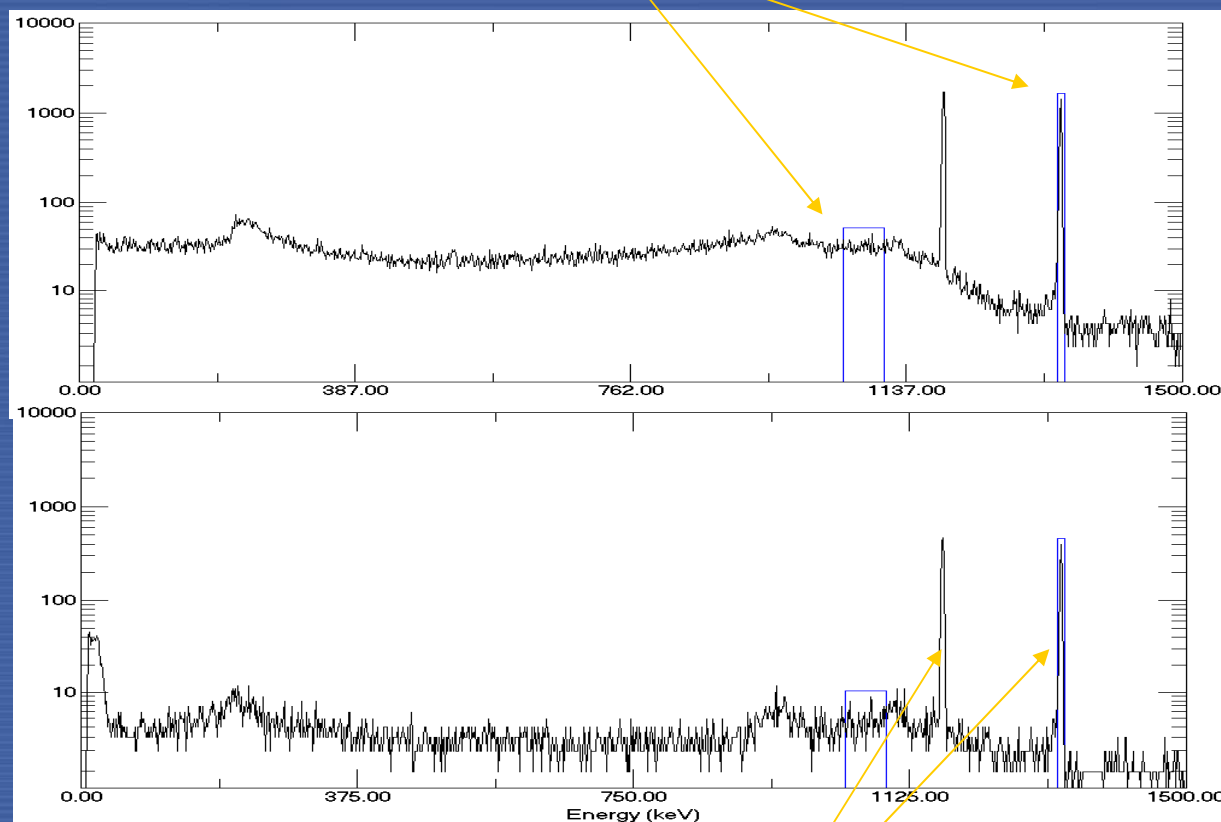
The Anti-Compton Spectrometer Results

^{60}Co : A= 2,8

P/C=57

Direct mode

Anti-Compton mode



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P/C=160

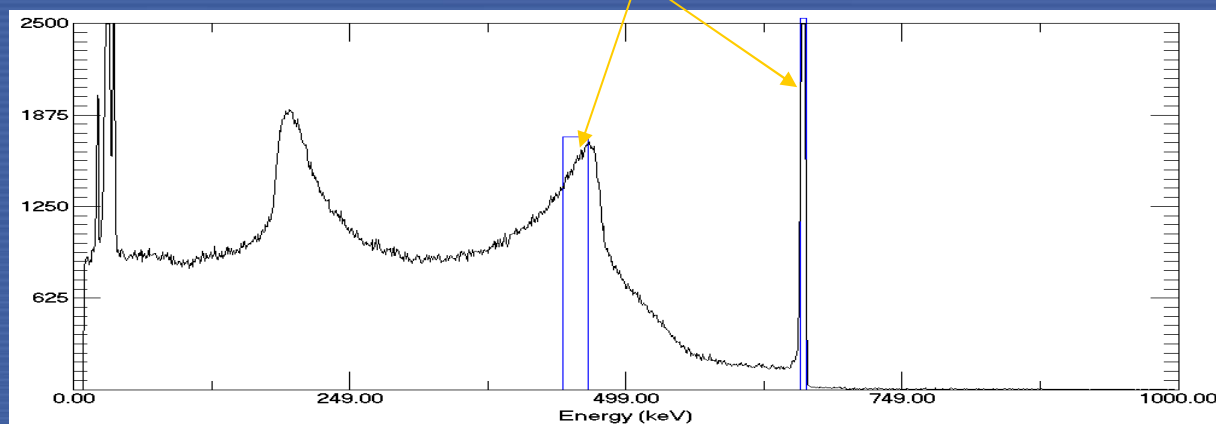
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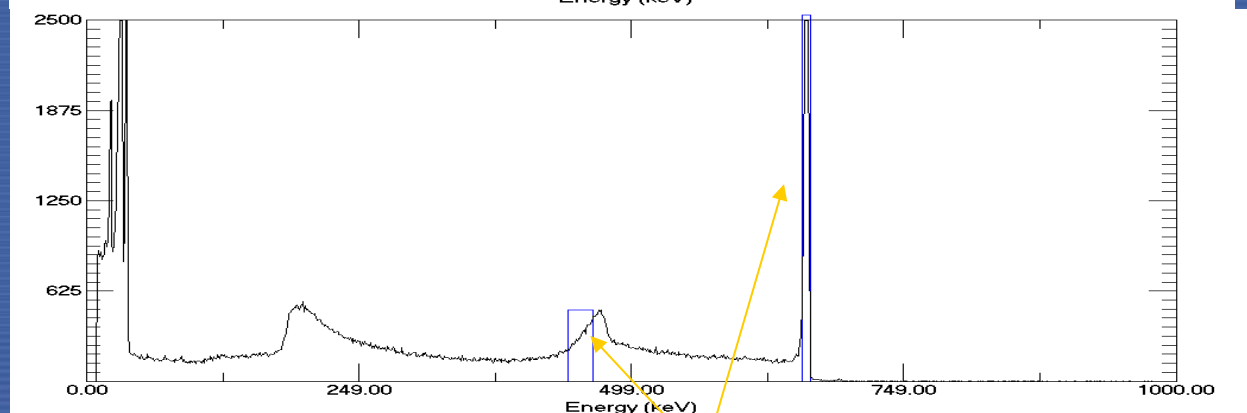
The Anti-Compton Spectrometer Results

^{137}Cs : A = 4,7

Direct mode



Anti-Compton mode



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$P/C = 427$

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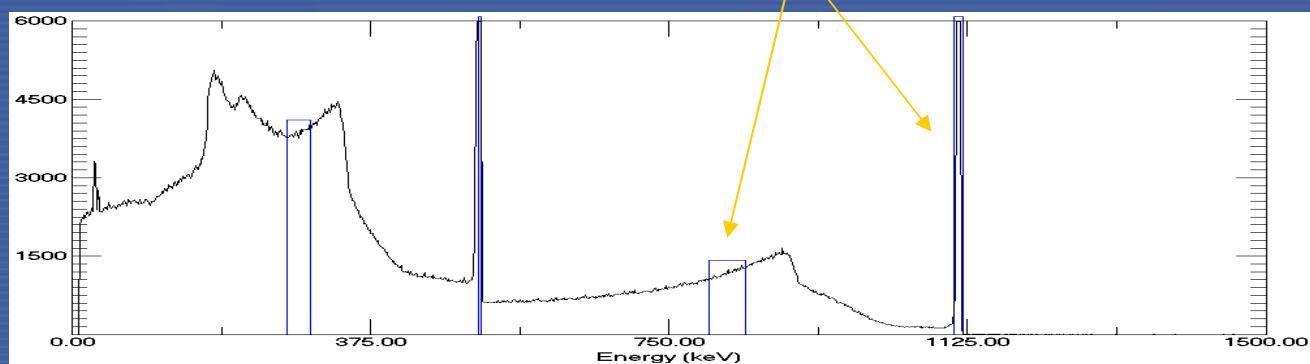
The Anti-Compton Spectrometer Results

^{85}Sr : A= ??

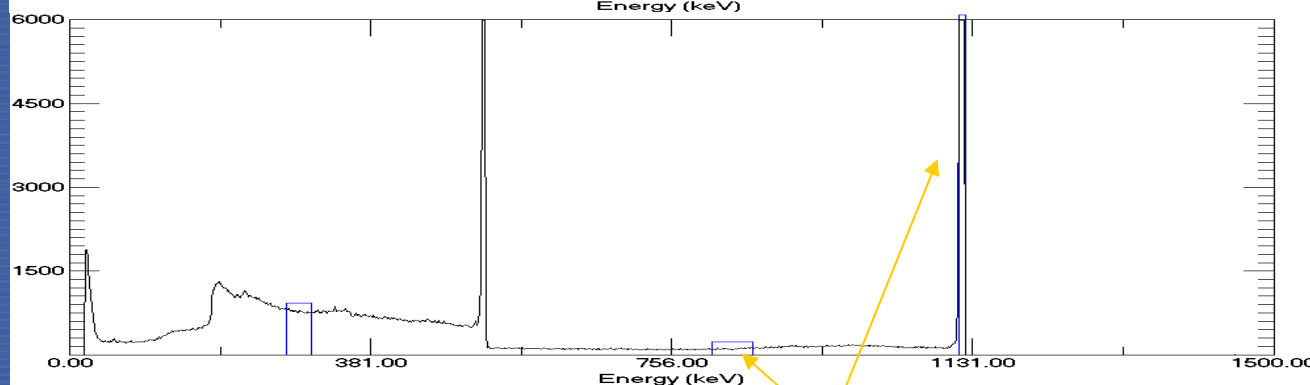
^{65}Zn : A= 11,5

P/C = 86

Direct mode



Anti-Compton mode



P/C= 960



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The Anti-Compton Spectrometer and γ - γ Coincidences



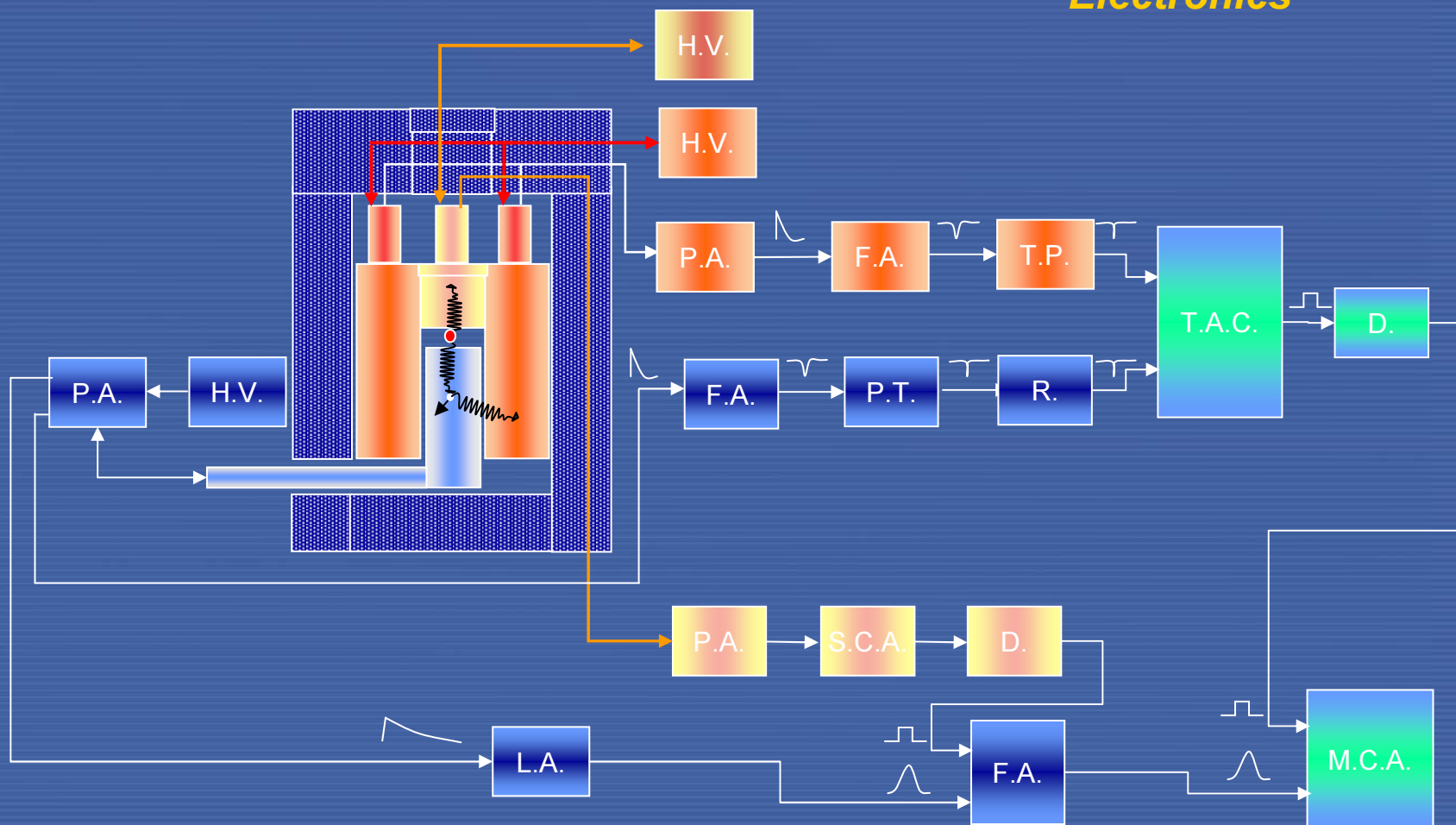
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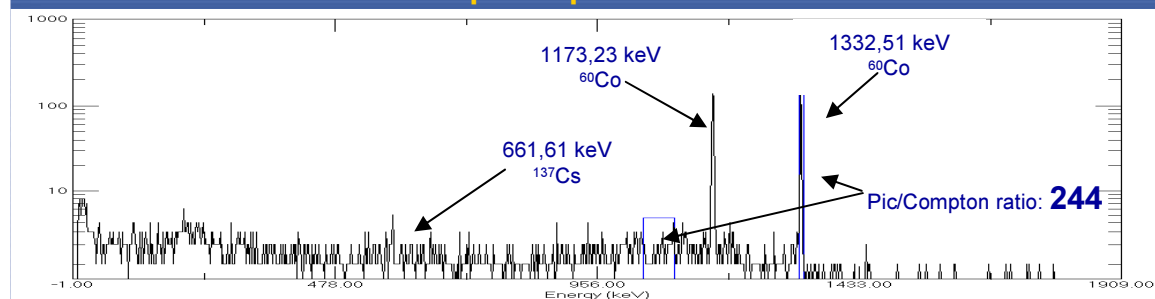
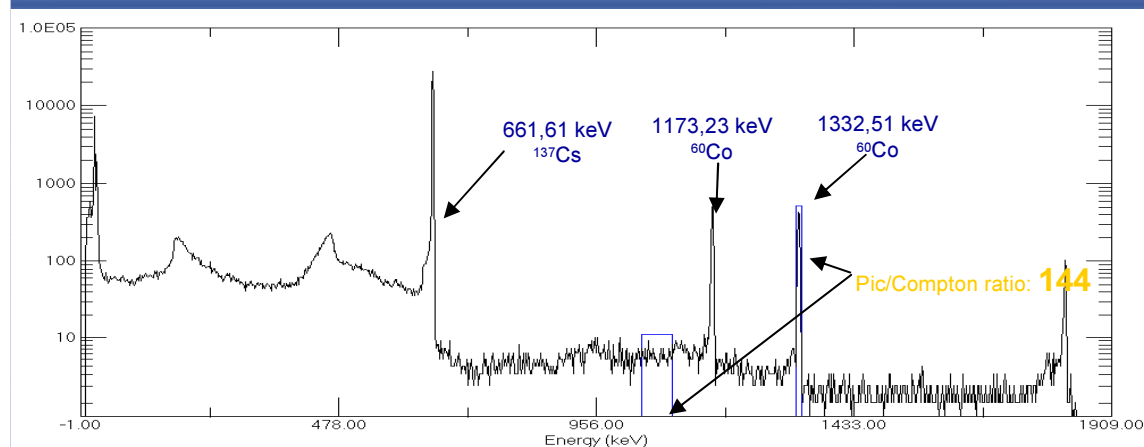
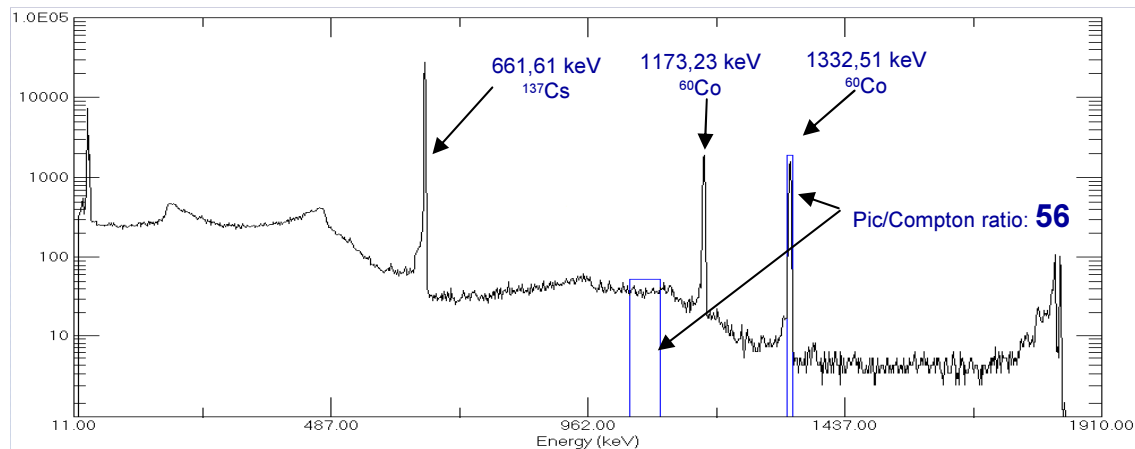
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The Anti-Compton Spectrometer and γ - γ Coincidences

Electronics





γ - γ Coincidence + anti-Compton Spectrometer : Results



γ - γ coincidence + Anti-Compton $^{60}\text{Co} + ^{137}\text{Cs}$
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The new techniques have opened doors for investigations

- **which previously required too large samples**
- **were not possible because of lack of sensitivity**
- **were not possible because of lack of precision**

Conclusion

GOALS : ACHIEVED !

- ✓ - To decrease the background and to increase the sensitivity of the gamma spectrometers: 0.02 cps between 20 et 2500 keV using 100% to 200% efficiency HPGe detector
- ✓ - To decrease the size of the Marine Samples: factor of 10
- ✓ - To decrease the measurement duration: factor of 5

More than 2000 samples has been measured since 2003

